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20. Abstract

This report is a summary of the state-of-the-art and of trends in development in the field of quality control in complex, highly automated production systems. Special emphasis is given to the development and use of modern optical sensor systems and components in industrial metrology. The report compares and contrasts accomplishments in the field in both the USA and the Federal Republic of Germany.

Institut für Produktionstechnik und Automatisierung, Stuttgart

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IPA

AUTOMATIC SYSTEMS FOR INSPECTION AND CONTROL OF COMPLEX PRODUCTION SYSTEMS

-STATE OF THE ART AND TRENDS OF DEVELOPMENT IN THE U.S.A. AND IN THE FEDERAL REPUBLIC OF GERMANY

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INTRODUCTION

This report is a summary of the state of the art and of trends in development in the field of quality control in complex, highly automated production systems. Special emphasis is given to the development and use of modern optical sensor systems and components in industrial metrology. The report compares and contrasts accomplishments in the field in both the USA and the Federal Republic of Germany. The comparison was made possible by an extensive visit to the USA arranged by the US Air Force European Office of Aerospace Research and Development (EOARD) at the request of the Air Force Integrated Computer Aided Manufacturing Project (ICAM). The authors visited Air Force, industrial and government laboratories engaged in research in modern quality control techniques. This visit is summarized in the next section of this report.

Sections 3 and 4 discuss trends in development in the field of quality control and quality assurance and activities respectively, at the Institut für Produktionstechnik und Automatisierung (IPA). Section 5 contains detailed examples of visual inspection systems for quality assurance.

The IPA in Stuttgart, West Germany, is an Institute of the Fraunhofer Society. Applied research in the field of production technology and organization is done with a staff of about two hundred people. Support for this research comes either from direct contract with industry or is sponsored by public funding.

One of the main working areas is the application of industrial robots in highly flexible production systems. A lot of peripheral problems are significant for the integration of such systems; human aspects as well as economic considerations have to be dealt with.

The flexibility of an industrial robot is limited by the ability of its sensors to react to changing working conditions. The wide range of optical sensors together with sophisticated electronics show the way for solving such problems today. Furthermore, the basic components of soft- and hardware of these modules are used in the field of measurement and quality control. The automation of visual inspections seems especially now to be possible under economic conditions.

JOURNEY REPORT

On behalf of EOARD, members of the IPA staff went on a journey through the USA to gain a deeper insight in the American activities in research and development in the field of robot and sensor technology. During this journey, they visited several industrial businesses and research institutes, not all of which were working under the ICAM project. The itinerary is shown below:

ITINERARY

DATE	PLACE OF VISIT
6.10	Materials Laboratory (MLTC) Wright-Patterson AFB Dayton, Ohio
7.10	Cincinnati Milacron Cincinnati, Ohio
8.10	McDonnell Douglas Aircraft and Automation St. Louis, Missouri
9.10	Chrysler Corporation Huntsville Electronics Division Huntsville, Alabama
10.10	General Dynamics Fort Worth, Texas
13.10	Stanford Research Institute Menlo Park, California and Unimation West Mountain View, California
14.10	Stanford University Dept. of Mechanical Engineering and Dept. of Computer Science, Artificial Intelligence Laboratory Palo Alto, California
15.10	Jet Propulsion Laboratory Pasadena, California
17.10	National Bureau of Standards Washington, D.C.

Lt. G.E. Mayer of the Materials Laboratory, AF Wright Aeronautical Laboratories, Wright-Patterson AFB gave an introduction to the ICAM project. In this connection, he also

emphasized the cooperation with General Dynamics (Fort Worth, Texas) and McDonnell Douglas Automation Corporation (St. Louis, Missouri), where aircraft parts are drilled by Cincinnati Milacron robots or riveted in manufacturing cells. Specially developed sensors /1/ and the use of several TV cameras for part identification are some characteristics of the advanced state of development of American robotic systems./2/.
The handling of parts using very simple sensor equipment was demonstrated at Cincinnati Milacron. Merton D. Corwin, manager of the Department of Robot Research and Development informed in detail about future trends in this area. Cincinnati's new machine, the T^3R^3, has a very comfortable continuous path control with a lot of software diagnostic tools for supervision. Transformation of work-piece coordinates to robotic coordinates is fully achieved by the control processor. Significant fix-points, e.g. the tool center, can be shifted anywhere within the workspace.
Chrysler Corporation, Huntsville Electronics Division, Alabama, demonstrated some optical sensors and sensor systems, one of which was fully integrated in a production line. This system was being used for inspecting PCB's. A two-dimensional laser scanner detects the presence or absence of a lead in the respective boring. The geometry of the bore pattern is programmed via a "teach-in" procedure. Errors, if any, are given the appropriate number from the bore pattern. These numbers are also made available for further use.
Another system was at the moment in the testing phase. Its purpose is to scan large parts. The advantage of this system is that it can be used with relatively simple data processing equipment. It should be noted that both these projects are not supported by ICAM.
At General Dynamics, Fort Worth, Texas, two ICAM-funded projects are in application, another one is under consideration and will be carried by General Dynamics itself.
All three are manufacturing cells for drilling of aircraft parts with different sizes and shapes using Cincinnati Milacron robots. Due to the lack of position accuracy required for high precision

drilling, mechanical aids are used for guiding and fixing the drilling tool as well as other gripper-tool combinations which can be interchanged automatically.

Concerning investments, General Dynamics does not seem to be a typical applier; the pay-off rates accepted might not be transferred to other branches of industrial production without further considerations.

At Stanford Research Institute, Menlo Park, California, David Nitzan, Program Manager for Industrial Automation gave a brief overview of future tasks and projects. The automation of visual inspection is one the most significant topics for the coming years.

At Stanford University, robots are used for the complete assembly of flashlights, sprinkler heads, etc.; these robots make direct responses to speech commands /3/, and they permit manipulations while moving.

Changes in reference point and in position, which may be caused by collision of the robot or maintenance, are corrected automatically with "Puma" of Unimation West (Mountain View). The robot can also be adapted in its movements to a running assembly line, and it can thus move in synchronism with the assembly line.

The progress made by NASA's Jet Propulsion Lab (Pasadena, California), where research and development activities are made in connection with space operations, deserves special mention. One of the interesting developments is a manipulator mounted on a vehicle, equipped with force and torque sensors and optically linked with the outside world via two camera systems, and the "voice control" for acting on a "space shuttle" controller by acoustic means. A microprocessor-controlled device for detection of the contacted surfaces to be used within the gripper zone of industrial robots was demonstrated; this device also shows the gripping forces active at a given moment in a contact matrix.

The problem of the gripper-interface standardization, which is

not only specific to the USA, is dealt with by the National Bureau of Standards (NBS, Washington, D.C.); this Bureau has been extremely successful in the development of gripper systems (as e.g. in Puma robots).

References relating to the text:

/1/ Nitzan, D.: Proceedings of MIDCON/79, Chicago, IL, 6.-8. November 1979

/2/ Eastwood, M.A.: McDonell Douglas Automation Co., St. Louis, September 8, 1980; Robotic System for Aerospace Batch Manufacturing

/3/ Nitzan, D.; Rosen, C.A.: IEEE Transactions on Computers, Vol. C-25, No. 12, December 1976

/4/ a) Freese, F.; Geise, P.: Chrysler Corporation, Huntsville Electronic Division; A Laser-scanner for automatic inspection of printed wiring boards

b) Geise, P.; George, E.: Chrysler Co., Huntsville Electronic Division; Axle Shaft Optical Inspection System

TRENDS OF DEVELOPMENT

Within the US, the ICAM Program is the most comprehensive effort to improve productivity through utilization of advanced technology. The following is a description of the ICAM Program as perceived by the authors.

Influenced by the rapidly changing conditions of science and technology and the steadily growing competition from abroad, the ICAM project was created under the leadership of the USAF and with the support of the United States Department of Defense. When the project began in 1977, the starting point was a cooperation among private and public institutions and American industrial businesses aiming at the rapid advancement of scientific and technological progress and its introduction into application-related practical work.

It is quite natural in such a complicated venture that the first task was to clarify questions of organization and to lay down a uniform course of action. This included the standardization of programming languages and development of an architecture of manufacturing which are used by everyone involved in ICAM.
In the foreground are such factors as economy in the design and development of complex flexible production systems; the replacement of man, whose capability is restricted with respect to specialized sensor problems, by highly specialized sensors; the reduction in the implementation period of compatible, standardized methods; etc., where these factors are regarded as ideal goals. Particularly in the production of military products and the problems that exist in this field (small batches, frequently changing products, great accuracy and reliability, etc.), improvements are to be obtained on these lines.

The field of sheet-metal working has been chosen to serve as an example in demonstrating the effectiveness of ICAM technology. The modular components developed along this line will then be ready for use in the ICAM factory, as it has been called.

Up to the end of 1980, progress mainly emerged in the software field. This involved the software analysis of existing programs and their potential integration into the ICAM project. The programs are modular in structure, so that the implementation of separate modules is made possible in individual industries; the main benefit is however to be drawn from the fully integrated system. The computer is used on all levels to support and check decisions; and it, for example, organizes jointing and machining cells.

As shown by the ICAM reports available, many sectors of the ICAM project have already been included in the current investigations. Among the sectors still open, there is above all one that can also be seen in conjunction with the activities going on at IPA; this is the sector: Test, Inspect, Evaluate, Quality Assurance.

U.S. AIR FORCE
INTEGRATED COMPUTER AIDED MANUFACTURING

Investigations into the complex problems of quality control and quality assurance are given much attention in the Federal Republic in general and at IPA in particular. As a result of energy and raw materials becoming scarcer, it is no longer acceptable to achieve quality by quantity. A product under

development must be subjected to inspection prior to, during, and after working on it, so as to keep rejects as low as possible. The quality characteristic "reliability" not only plays an important role in the military field, although it is of greater significance there. It is particularly important in complicated technical equipment where reliability is endangered by a large number of individual components, since the failure of a single component may result in the breakdown of the total system.
For assuring the quality of a product, it is necessary to examine the disturbance variables that may occur randomly or systematically-the human worker, the methods used in production, the machines and the materials involved- as to their effects and the frequency with which they occur.

At IPA, research and development work has been performed in the field of noncontact sensors, in particular optical sensors, for a couple of years; among other things, this may involve the detection of surface imperfections (e.g. shrink holes, rusty spots, defects and irregularities of materials), the measurement of geometrical bodies (such as screws, bolts, pressed parts) and the determination of the surface roughness of technical surfaces.

To demonstrate the development in this field in more detail, some activities will be discussed at length.

IPA ACTIVITIES

Optical measurement of surface roughness

The research activities in the field of optical roughness measurement on workpiece surfaces have experienced a staggering rate of development since 1972. Sensors, and particularly those developed in Japan have been able to produce good results. Their use on the shop floor has not however materialized up to the present time.

The investigations carried out in this field at IPA from 1975 to 1979 produced comparable results (Figure 1). In 1979/1980 a somewhat modified new technique for optical roughness measurement was eventually developed, and it is likely that this new technique will soon be used on the shop floor. In this setup, called "white-light-method", there is a white-light bulb (halogen bulb), whose light falls on the surface to be measured. The back-scattered light is deflected via a beam splitter and projected on the picture level by the image forming section. An additional constant light overlay linearizes the characteristic curve and largely reduces the declining trend in the "peak-to-valley pattern" (Figure 2).

On the out-of-focus level, the optical information of the surface to be measured is converted into electronic information through a photosensitive sensor (as e.g. a photomultiplier, or a semiconductor operational amplifier with a light-sensitive diode). In a proper statistical evaluation of the current or voltage values carried out by a computer (HP 9815A, COMMODORE PET) linked into the system, it is possible to make clear assignments of the measured contrast values to the surface parameter (R_a, R_q).

When the current research work in this field is continued in an intensive manner, there is every likelihood that a prototype of this roughness sensor will be implemented in 1981/1982.

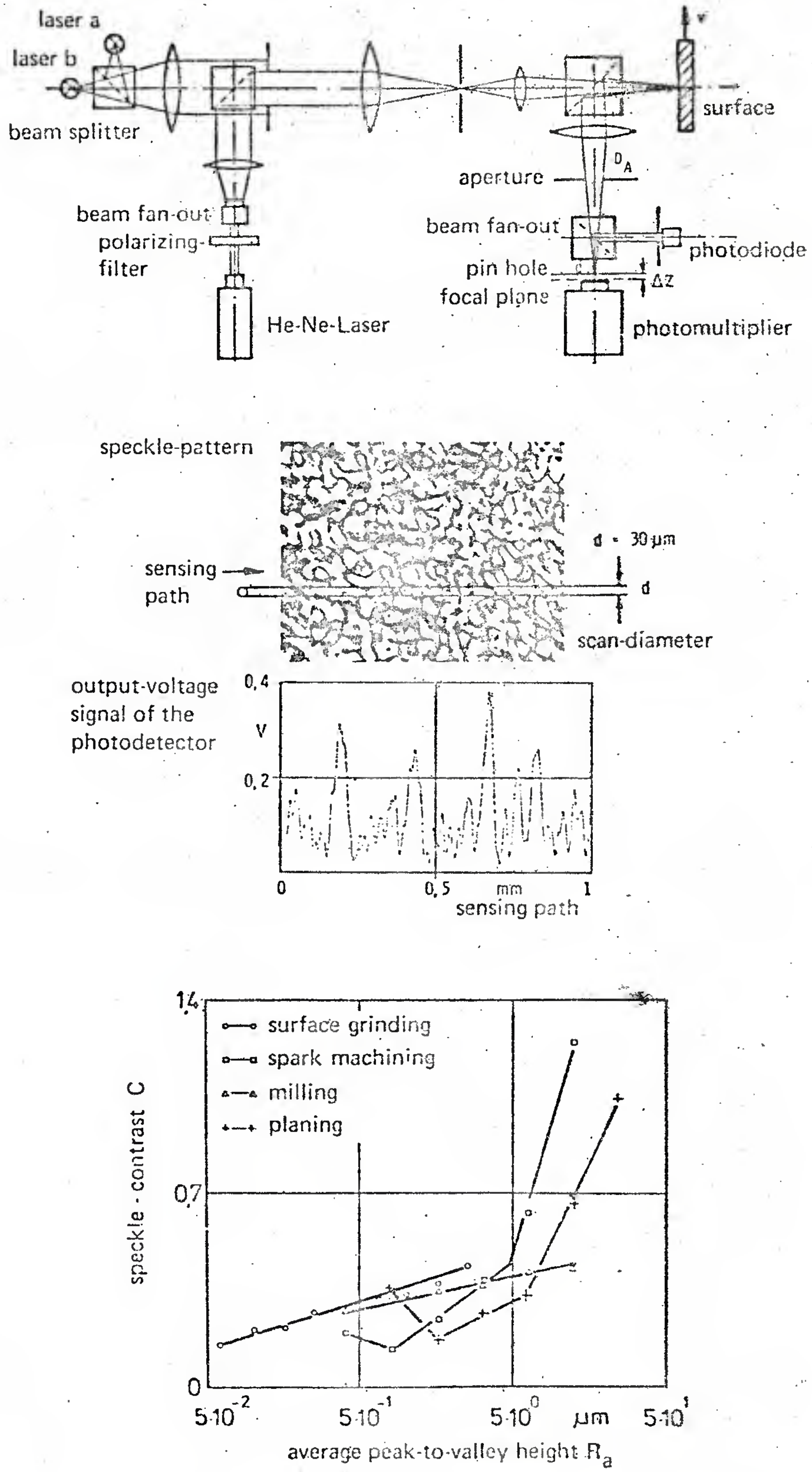
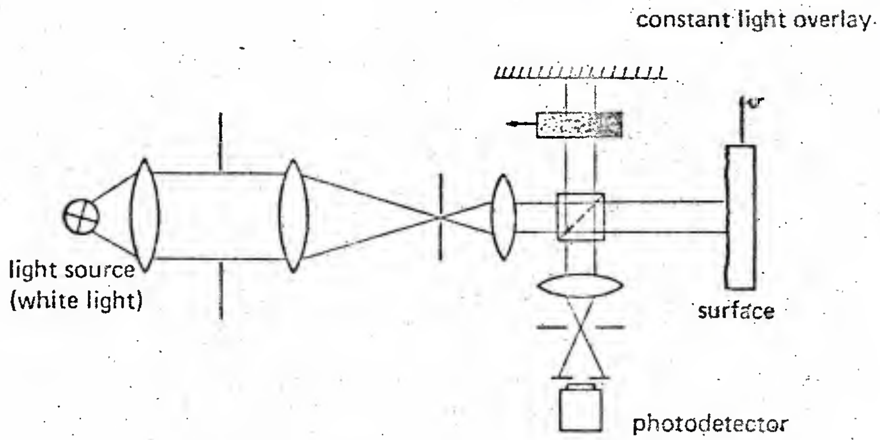


Figure 1 : Speckle contrast method for measuring the roughness on workpiece surfaces



optical set-up principle

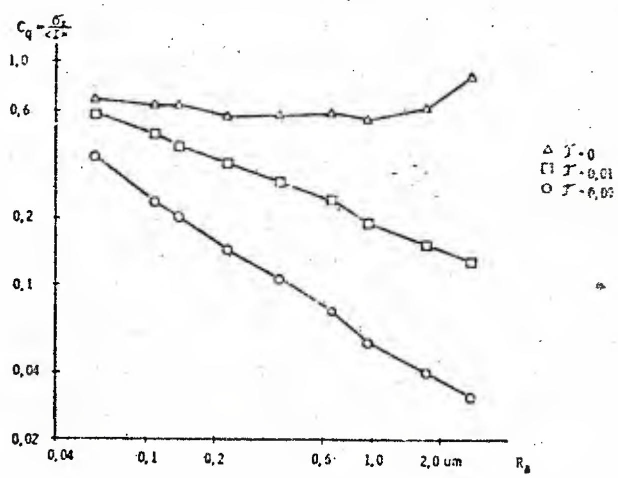


Figure 2 : White-Light-Method for measuring the roughness on workpiece surfaces. Characteristic curves measured ($\tau = I/I_o$ constant light overlay)

Linear and area arrays of photodiodes

The advancing development in semiconductor technology made available optical sensors arranged in linear form or in arrays. These sensors can be used for optical quality control.

Screw-bolt inspection

This inspection uses the linear diodes, with the diodes being transversely arranged to the screw bolt´s axis. If the screw bolt is moved in axial direction, the individual diodes arranged in a row will be illuminated or dimmed, depending on the contour involved. By counting the bright/ dark elements, a length assignment can be made, depending on the optical set-up involved.

The values obtained in the individual line scans are then linked and further processed by a PDP 11/03 computer, which determines the characteristic features of the screw bolt such as pitch, thread angle, completeness, etc. in accordance with the objectives prescribed. The software permits the entry of sample pieces by the "teach-in" method, and a comparison can then be made with actual parts.

At the present time, the state of development and the reliability of the linear diodes still leave the array diodes somewhat in the background. But arrays will be used for tasks in the future, which so far have exclusively been reserved for linear diodes.

This development work is performed by IPA in parallel, i.e. both linear and array diodes are used to solve problems, so that linear diodes can immediately be replaced by arrays, if the technological development goes on at this rapid rate.

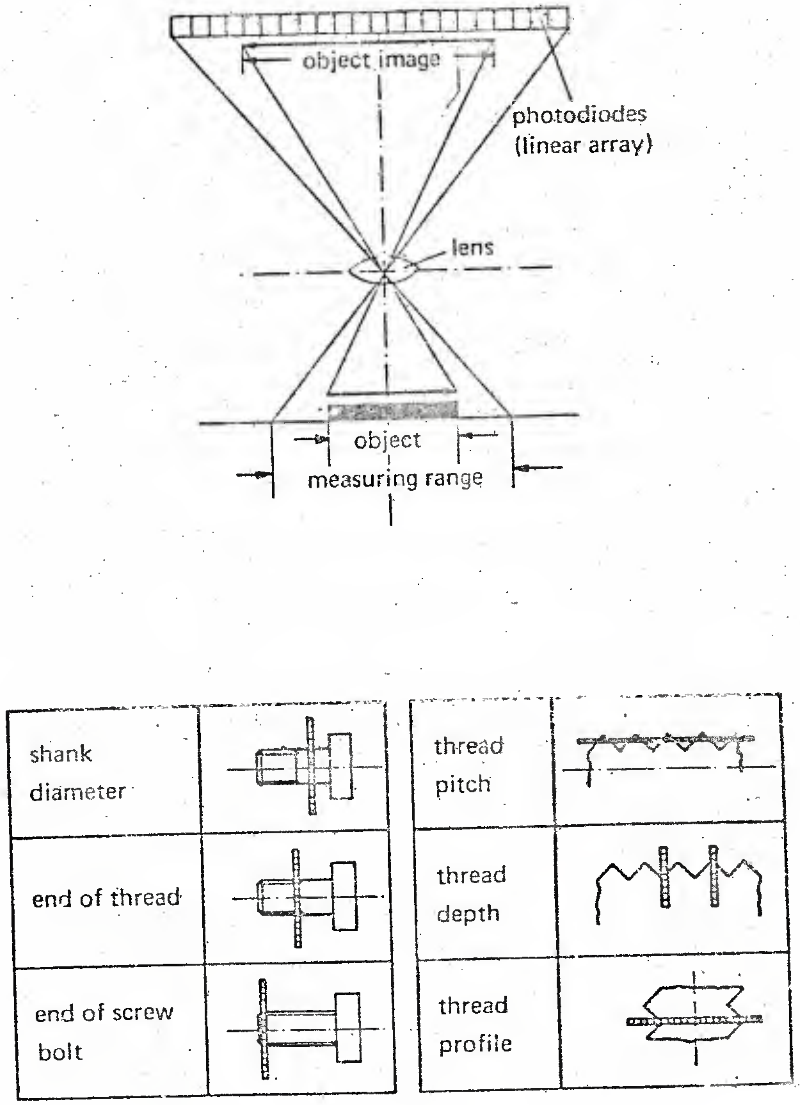
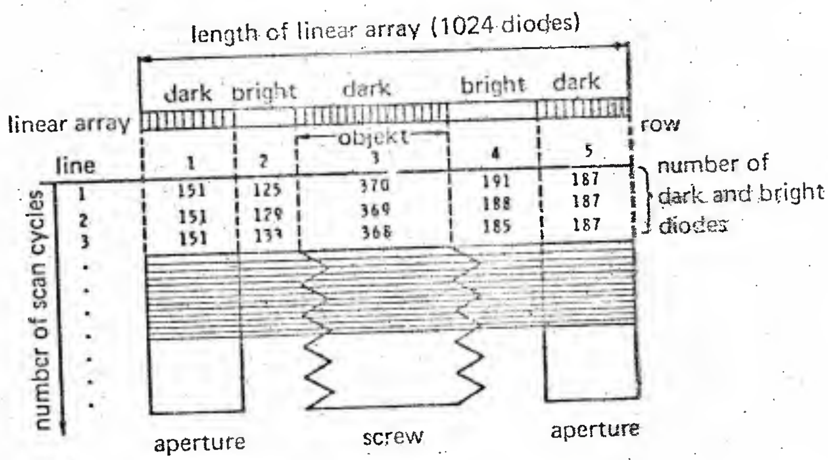


Figure 3 : Linear diodes used in screw-bolt inspection (principle)



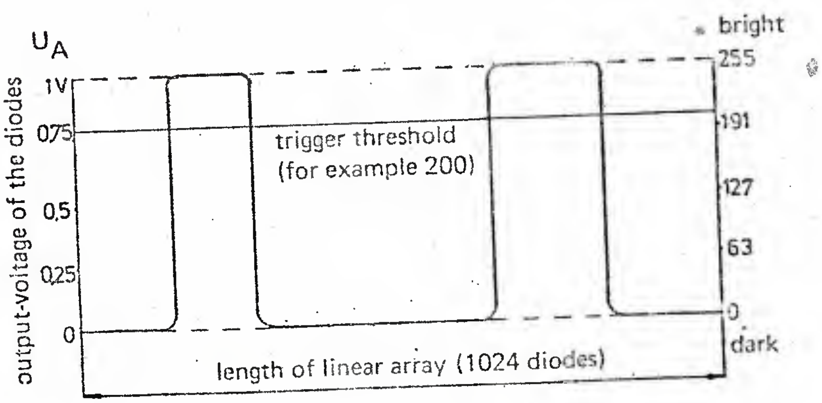


Figure 4 : Measuring signals in screw-bolt inspection

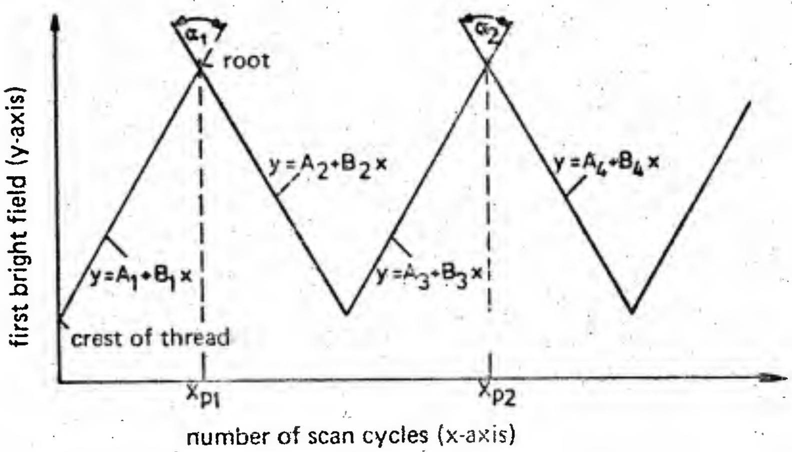


Figure 5 : Signal processing in screw-bolt inspection

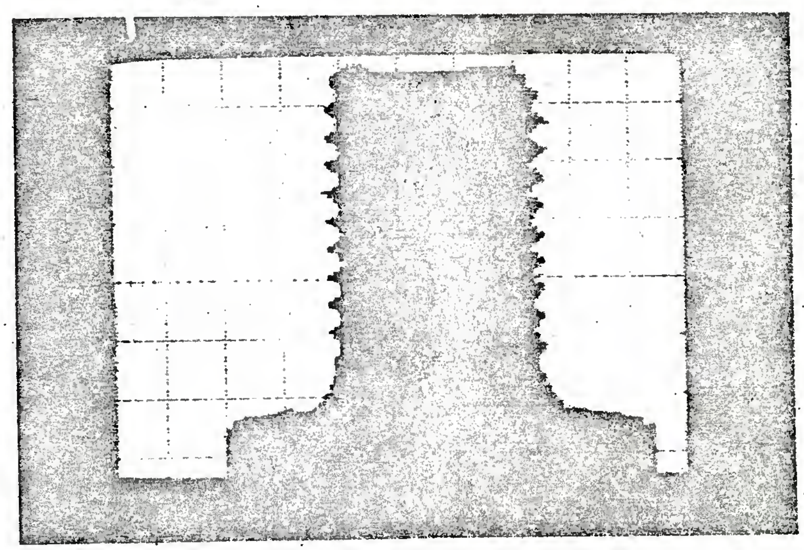


Figure 6 : Diode array used in screw-bolt inspection
- Monitor image of a thread (100x100 diode matrix)

Piston-ring inspection

Another field of application of the linear diode camera is the optical inspection of surface characteristics on piston rings. The purpose of this inspection is the detection of surface defects (shrink holes, rusty spots, material eruptions etc.) which exceed a predetermined value. The sequence of measurement is as follows:

The clamped piston ring is turned via a movable table (rotary table). The scan start is determined on the basis of the signals coming from the linear diodes, and measurements will be made throughout the predetermined angle range. The individual error signals thus obtained will be accumulated and an error message will occur as soon as the tolerable cumulative error is exceeded. Piston rings falling below and exceeding the tolerance limits will be separated by connected-in electronically controlled mechanical equipment, and the piston rings can thus be detected as "go" or "no go".

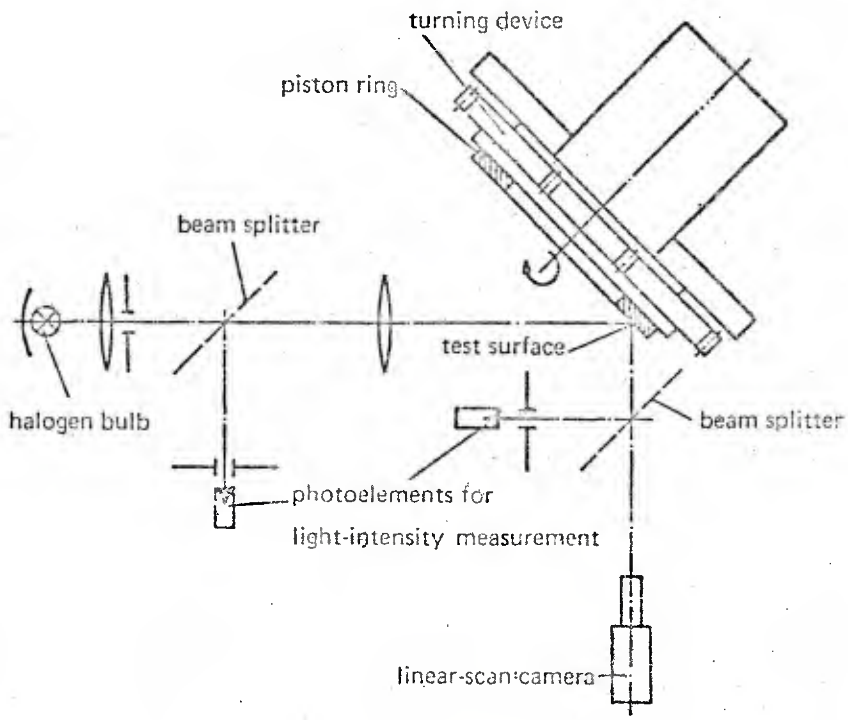


Figure 7 : Experimental set-up for piston-ring inspection

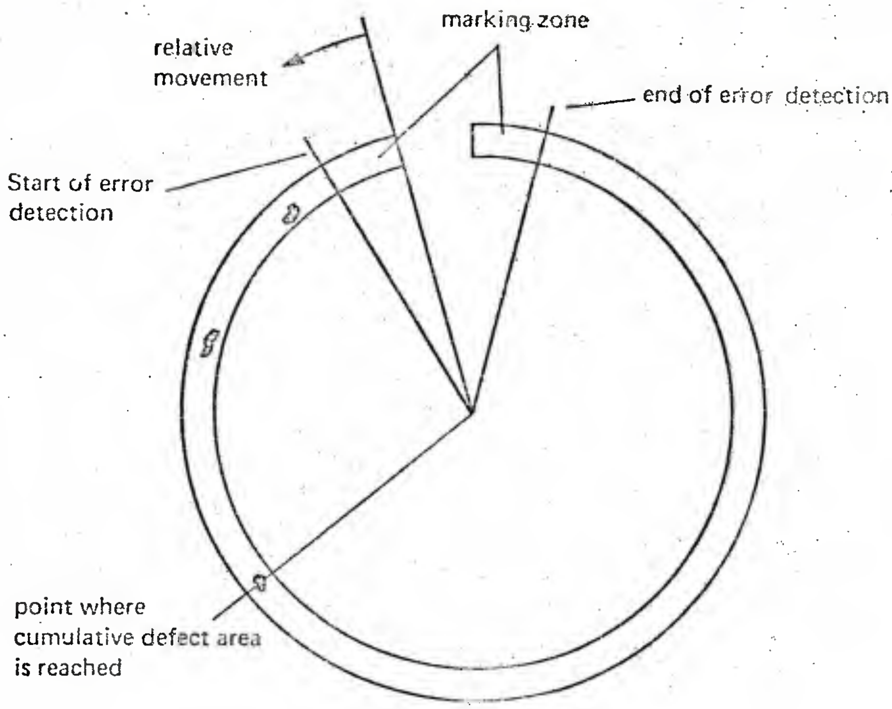


Figure 8 : Determination of measurement positions for a measurement cycle

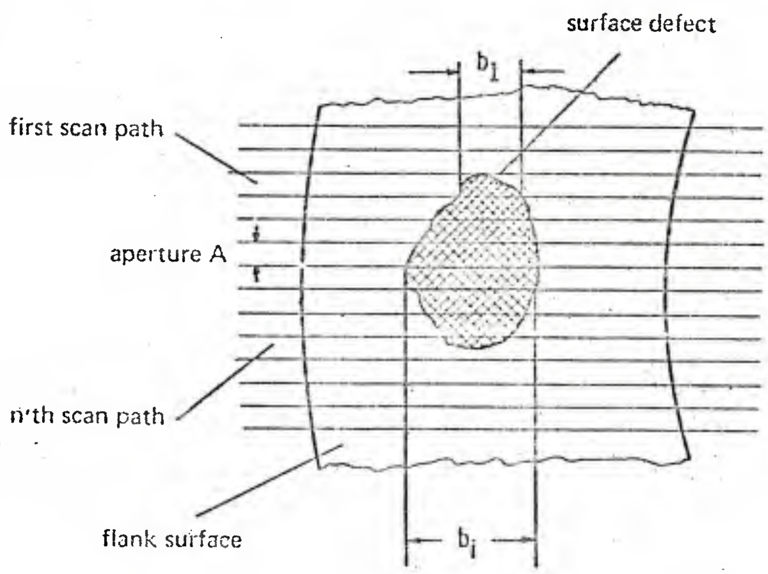


Figure 9 : Principle of covering the "defect areas"

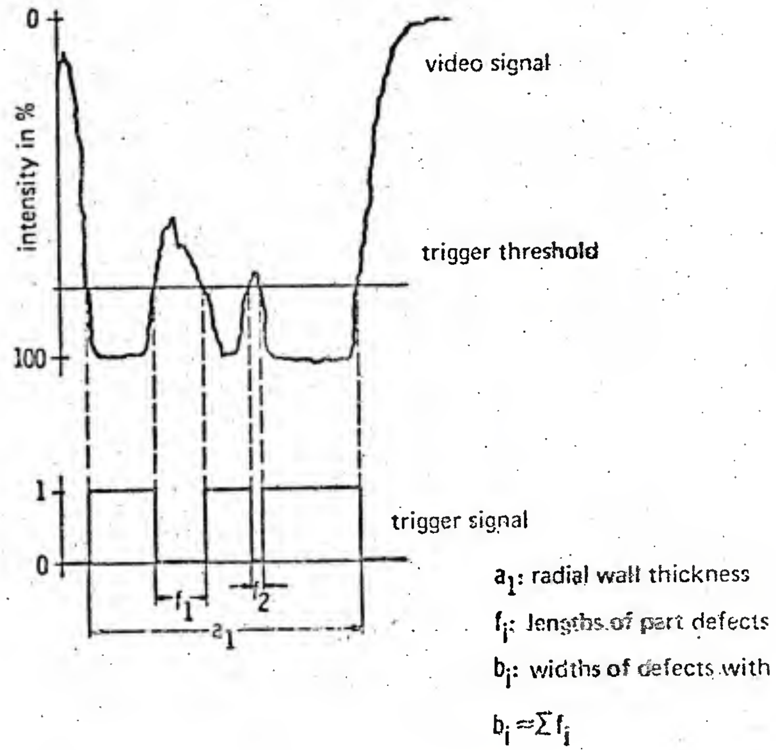


Figure 10 : Evaluating the video signal for determining the "width of defect"

Laser scanner

The laser scanner is a device which is suitable for measuring large dimensions (in the meter range) at great accuracy (in the range of 100 um). In these measurements, moving paper webs or metal lines can be inspected for holes, irregularities, inclusions, etc. Special peripheral computers permit flexibility in the selection of tolerance limits, so that an adaptation to the problems involved is possible without any major difficulties.

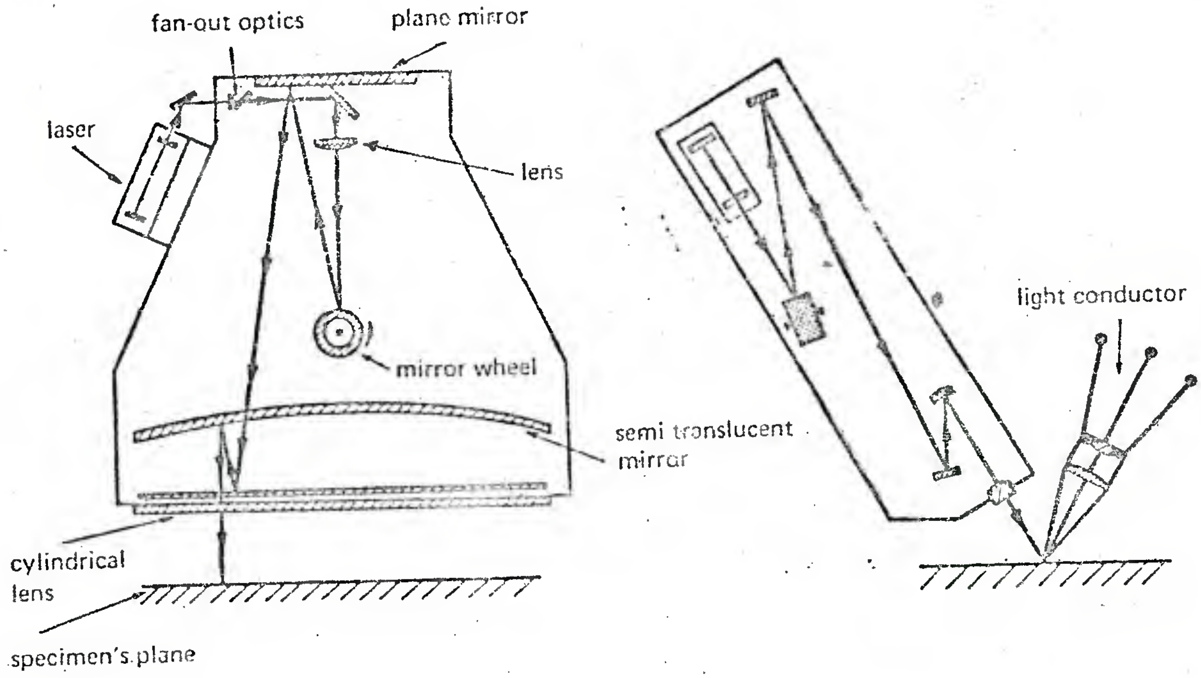


Figure 11 : Laser scan system for measuring large-size surfaces (metal line and paper web surfaces)

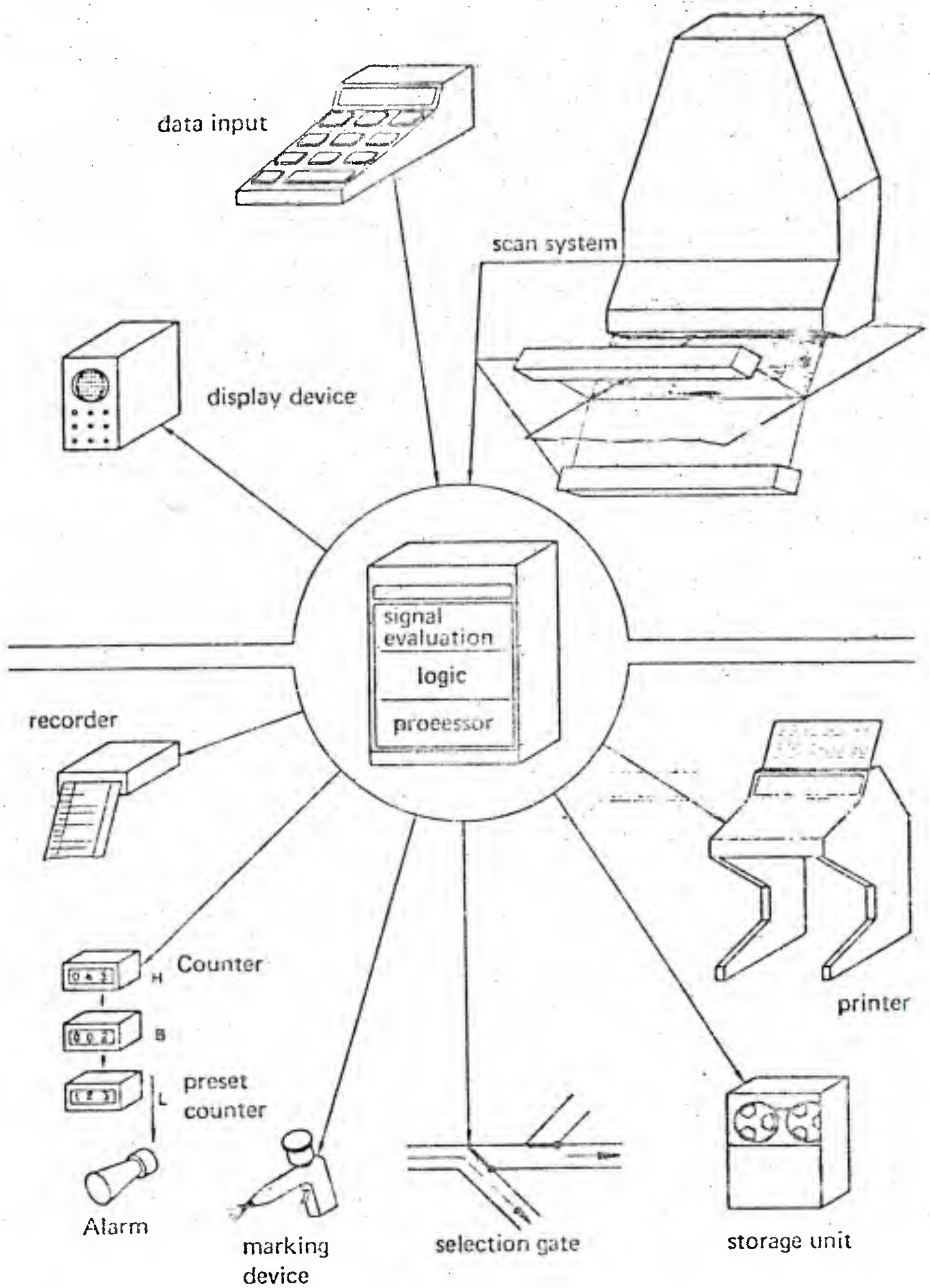


Figure 12 : Signal evaluation in the laser scanner

QUALITY ASSURANCE

IN VISUAL INSPECTION BY WAY OF EXAMPLE

Visual inspection and metrology

Typical visual inspection tasks are e.g. completeness tests during assembly or during production, surface tests, and tests to determine the shape and position, to the extent these can still be recognized by visual means.

The better the quality of the workpieces to be tested and the less frequent the sight inspector experiences a success in that he finds a defect,the more likely observation errors will occur.The efficiency of the visual inspector will reach a maximum degree of about 9o%,if he detects a defective part every 2o seconds on the average.His efficiency will decrease to approximately 6o%,if too little demand or excessive demand is made on him.

But it is not only the monotony linked with visual inspection work stations that makes visual inspection tasks problematic in the quality assurance environment,
but also miniaturization, particularly in the field of electronics, and the production speeds - these increasingly set limits to visual inspection.

Thus,endeavours to automate visual inspection will be made whenever it becomes necessary to objectify the visual inspection process, if the characteristics of the visual inspection tasks can no longer be detected by visual means, or if a visual inspection station has to be automated for reasons of time or cost.

One possibility to automate visual inspection stations is the use of picture-processing systems.

These systems consist of an image converter which takes the form of television cameras or diode arrays, more or less convenient mapped memories, a picture-processing section, and different output facilities.

The Fraunhofer-Institut für Produktionstechnik und Automatisierung has a number of such optoelectronic picture processing systems, which will be described in the following:

The knowledge of the advantages of television systems resulted in the fact that research and development work in this sector has been heavily pushed forward. The modern image data collection devices, however, supply such large volumes of data that it is no longer possible for man to evaluate them by manual-visual means. Only the drastic price fall in the process computer market made it possible to develop sensor systems coupled to computers, and this at relatively reasonable cost.

The interactive picture-processing system used at IPA is to serve as an example in the processing of the big data volumes to be handled. With a linear picture resolution of 512 by 512 picture elements, a gray-level resolution of 256 levels, and a picture-element scanning speed of nearly 15 MHz, the signal fields represent such an extremely big information volume which can only be evaluated by using special image processors. Since the operating speed of such sensor systems does not least of all play a decisive role, and as explained above with a standardized volume of image data to be handled, new approaches had to be found in attaining processing speeds that are adequate for the applications. The development of high-speed digital mapped memories in combination with processors for image preprocessing now provides the possibility to evaluate a picture scene within times acceptable in practical work.

The tasks of such sensor systems are very versatile. It is therefore of great importance to prepare a catalog of tasks, which permits the sensor system and its configuration to be allocated to the special test problems. The systems for picture processing necessary for the solution of such special evaluation jobs are expediently implemented through special hardware and software systems.

If one investigates the trend of development in the field of television picture-processing systems, it can be seen that a modular design of hardware and software is given preference, because of the wide range of applications. The future fields of application of automatically operating television picture-processing systems can be divided into five fields of application, with tasks allocated accordingly:

- industrial applications
- military applications
- biomedical applications
- remote reconnaissance of planets
- special applications.

Out of this catalog of applications, industrial inspection problems will be dealt with here, and in particular the problems of visual inspection and quality control.

Two television picture-processing systems are available for research purposes and for carrying out jobs received from industry. One picture-processing system, the scanning system, makes it possible to take over part of the information from any position of the picture field and to process this information. The interactive picture-processing system is equipped with a real-time mapped memory, in which a complete television picture with 256 gray levels per picture element can be digitized and frozen in real time. Both systems will be explained in more detail on the following pages.

TV scanning system

This system for picture processing consists of a television camera manufactured by HAMAMATSU (Figure 13) and it is characterized by its high stability, high responsiveness, high resolution (1024 x 1024 picture elements) and low wear due to the burnt-in raster. The analog pictorial data is digitized in the camera´s control unit (Figure 14) and fed into the process computer via a parallel interface. Furthermore, the camera´s control unit also controls the camera, the acceptance of data; it is also possible to perform image-preprocessing with this unit. It is e.g. possible to improve the linearity capabilities of the camera and to generate binary images using a gray-level threshold that can be manually selected.

The color converter permits colors to be allocated to a black-and-white picture, thus making it into a multi-color picture. By suitable color allocations, the color converter becomes a valuable component in the visual judgement of an object image. Particularly in the illumination of homogeneous gray fields and in contrast examinations, minor deviations in the gray level can only be visually represented and perceived with the allocation of false colors.

Real-time system

This system, manufactured by Micro Consultants Ltd. of type "Intellect" is capable of digitizing a video picture in real time, and then storing it in a semiconductor memory. In this form, the digital image can be conditioned by the computer and manipulated in any manner. The scanning frequency of 15 MHz of the 8-bit A/D converter does not only ensure great system accuracy, but also a high reproduction quality.

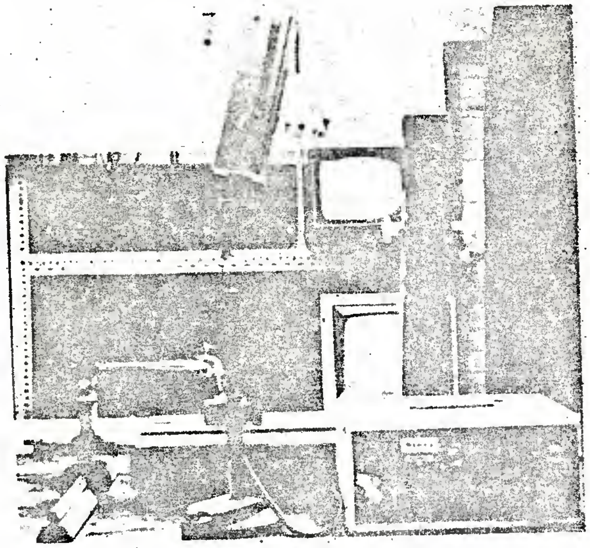


Figure 13 : Camera with endoscope attachment

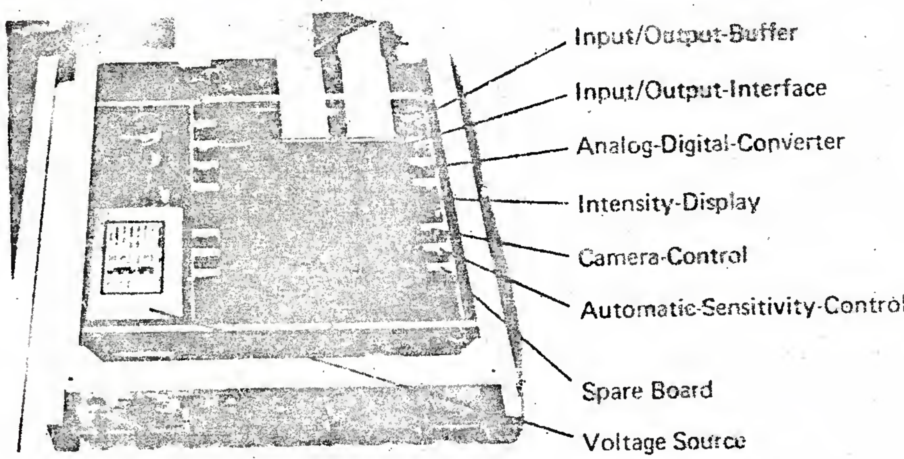


Figure 14 : Camera control unit

The core of the system is the semiconductor memory with a capacity of 256 times 512 words of 8 bits each for storing two fields, i.e. 256 lines with 512 picture elements for each line of storage space are available per field, with a resolution of 8 bits per element. Image line and image dot are each defined by a 9-bit address. Since the minicomputer has direct access to each individual image dot, it can take information out of the memory, read it in again or produce an image with regenerated data. Moreover, this makes the transfer rate dependent solely on the speed of the computer.Read and write operations in the memory are performed completely independently from one another, so that both synchronous movements (cameras) and asynchronous movements (e.g. electron microscope) will be possible.

This system permits numerous manipulations to be made under hardware and software control, as e.g.:

- relocation of the image in memory
- special marking of specific image sections
- image representation at reduced resolution
- image reversal
- writing two fields one above the other
- X-Y-coordinate determination of defined points
- color representation.

This system can also be linked to high-precision cameras, as e.g. to a camera of HAMAMATSU, or to any other television camera with BAS exit.

Software development

At the Fraunhofer-Institut für Produktionstechnik und Automatisierung, software for picture processing is developed for a wide range of applications.

The most important guiding principle in the development of software is a program architecture that is structured to a great extent,so that the possibility in software development of creating a modular software library as a universal application can be realized.

At the IPA a concept has been developed in addition, which permits the individual modules to be used in the most different picture-processing systems. Thus, software for geometry analysis is e.g. used on the somewhat slower operating scanning system as well as on the interactive picture-processing system. Moreover, it is possible to employ this software when using diode cameras with a one-dimensional field (1024 picture elements) in connection with a mechanically movable scanning table. This system is also used at the IPA.

The processing of simple binary images will not be as sufficient where tasks are mainly to be handled in quality assurance and in visual inspection. In these tasks, gray-level analyses - both statistical and discrete have to be performed.

Different methods of finding threshold values are used in binary picture processing. It is particularly in the geometry analysis where the finding of a suitable gray-level threshold is decisive.

Picture-enhancement programs are used for correcting linearity and individual shading effects, they can also eliminate faulty information or the invalidation of images.

Visual inspection tasks

Conventional video systems for inspection (visual inspection) of products and specimens nowadays readily lend themselves to connection of the commercially available sensors with an evaluating computer. Such systems permit the following tests to be automatically performed: completeness tests on simply assembled parts, damage to components, defects in workmanship, cleanness tests, preferred orientation tests on grinding operations, cracking tests on cast parts, and structure tests on biological preparations for examination under the microscope, etc. It is however a prerequisite for the automatic carrying out of such tasks to be performed with the television system that the characteristics to be evaluated provide clear contrast conditions through optimizing the illumination and object preparation and, if possible, lend themselves to be represented by a binary image.

As in the optical representation in the microscope, two types of representation are also distinguished when working with television sensor systems: working with throughlight illumination and/or vertical illumination. Under throughlight illumination, a workpiece is represented in its contour and its cut-outs. This form of illumination mostly permits the object in the scene to be clearly detected. One possible application of the throughlight mode is the inspection of plug connector strips or the position of the contacts in it.

Another field of application of television sensors in the throughlight mode is the inspection of glass containers in the food industry. This task is also performed in the throughlight mode, but it can only be automated in part, because of the considerable clock times.

Figure 15 : Plug connector strip as a test object

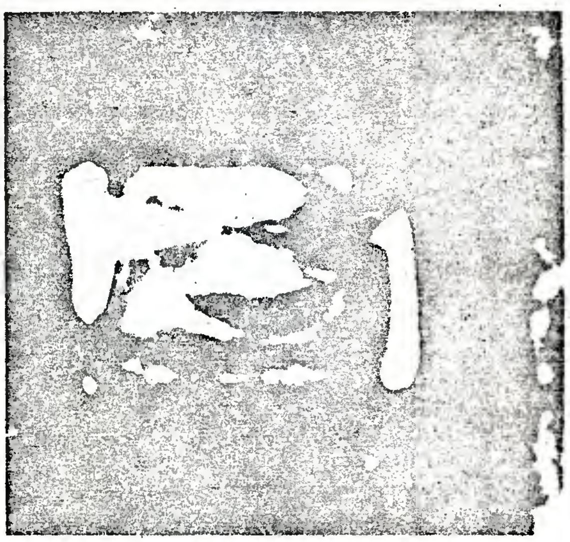


Figure 16 : Enlarged representation of defective terminals (away from center shift)

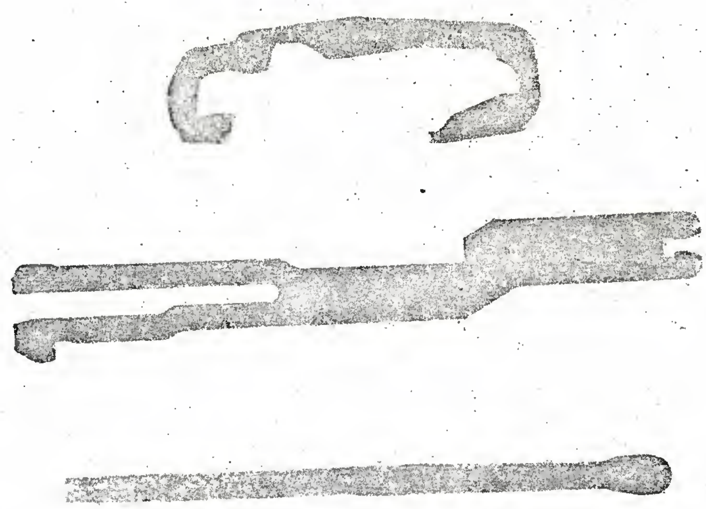


Figure 17 : Pressed-part inspection

The major part of visual inspection tasks is performed in the vertical illumination mode. In this field, very different visual inspection problems have been analyzed at our institute. The most frequently occuring tasks to be handled included:

- recognition of damage
- recognition of dirt conditions
- detection of assembly errors, and
- detection of faulty coating.

Inquiries regarding the examination of products for damage came from a wide variety of production sectors. Such inquiries came e.g. from the following sectors:

- automotive parts manufacturing
- manufacturing of food and drug containers
- pill manufacturing
- screw and bolt manufacturing
- manufacturing of electronic components, and
- manufacturing of wovens.

The tasks to be handled are to be represented with the aid of the following pictures (Figures 18 - 21), in the form of extracts.

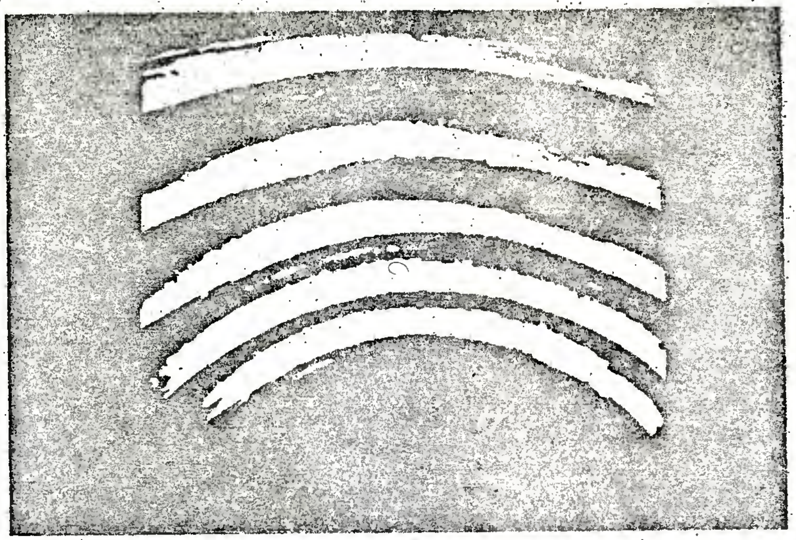


Figure 18 : Internal thread, without any defects

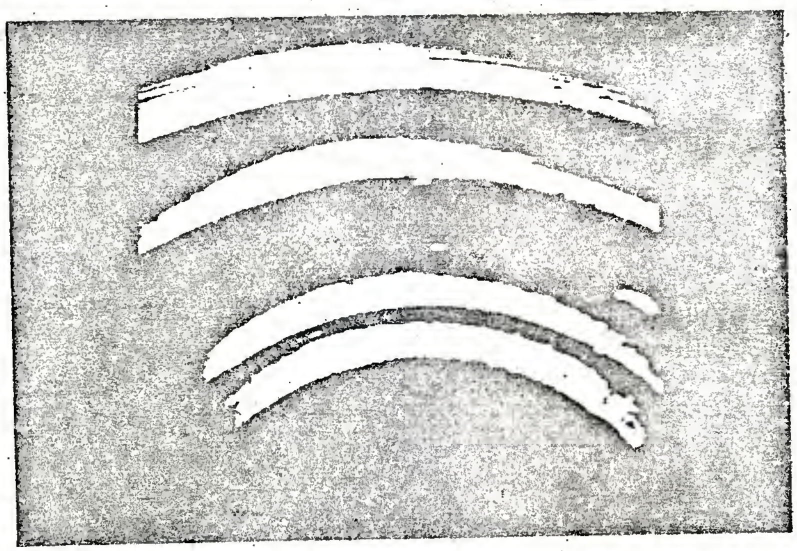


Figure 19 : Internal thread, with defects

Figure 20 : Testing a chip for defects (before bonding)

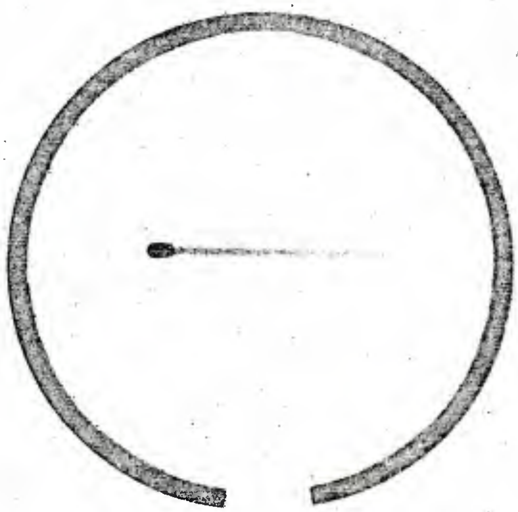


Figure 21 : Cracking and shrinkage test on piston rings

Apart from tests for damage, the cleanliness of the containers (bottles, cans, tubes, etc.) was of decisive importance, in particular in the field of the food and drug industries. The use of television sensor systems in these inspection jobs failed in this field of application because of the considerable clock times.

In the assembly environment, it is mainly the electronics industry that has an interest in an increased use of television sensor systems. The main inspection jobs in this field include the supervision of the assembly of printed circuits and the supervision of assembly work of plugs and small equipment.

A further field of application of television picture-processing systems is in the field of surface testing of coated plates. On the strength of the high resolution of these sensor systems (256 gray levels), they are in this field far superior to the human worker, who can cope with only about 20% (50 to 60 gray levels).

Applications in metrology

Press engineering has made considerable progress over the past few years. The use of multiple press tools makes it possible today to completely manufacture increasingly complex parts in rapid sequence. In contrast to this highly advanced production method, the quality-assuring measures for initial sample inspection and for in-production testing have not been further developed to the same extent. In initial sample inspection and in sampling tests, acceptance-test times from one to three days, carried out every one or two hours, are the rule for a full-time inspector. The high costs caused by the inevitable stop times are a burden for the "pfennig" product "pressed part".

The spectrum of parts manufactured in the press shop is very versatile. It includes very complicated workpieces (Figure 22) with a large number of different cut-outs, beads, and angular sections, but also workpieces of simple geometry, which can be manufactured in very large quantities.

The stroke rate of the machines is around 50 strokes per minute in complicated parts, and around 180 strokes in straightforward parts. Multiple tools are the rule.

Although the tools have long useful lives, there are important dimensions in which wear leads to quality problems in further working. Another problem is the breaking out of blanking punches. If not detected in time, this defect will result in high reject costs.

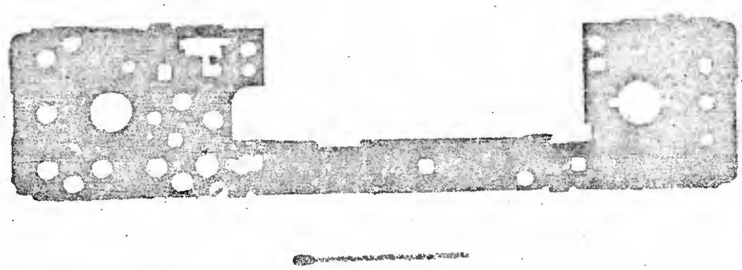


Figure 22 : Pressed part with complicated cut-outs

If an analysis is made of the measuring and supervision jobs performed on pressed parts, it can be seen that a limited number of partial tasks that can be standardized occur again and again. These are known to the engineer, and he can break down a complex inspection job into these partial tasks. If these metrological partial tasks are solved in terms of software and hardware, it will be possible to automatically inspect pressed parts with the aid of the test center after a teach-in phase (Figure 23).

Problem-orientated program modules are established for such partial tasks with the assistance of the built-in development system. These will then be assembled in a task-related manner.

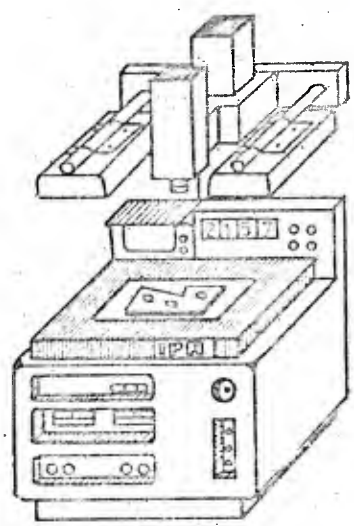


Figure 23 : Television test center for pressed parts

Just as in pressed parts, highly accurate precision-engineering workpieces also pose great problems in quality assurance. To test the bottom plate of a watch (Figure 24) today takes about three hours. In this case, too, the television measurement method can be used to advantage. Due to the extremely high demands made on the accuracy of such parts it is however necessary to increase the resolution of optoelectronic sensor systems by the inclusion of mechanically operating scanning tables. This combination permits shorter inspection times, and a quality-assurance system can thus be built which does not only orientate itself at the rather doubtful small sampling tests, but it receives more data from the faster operating control systems.

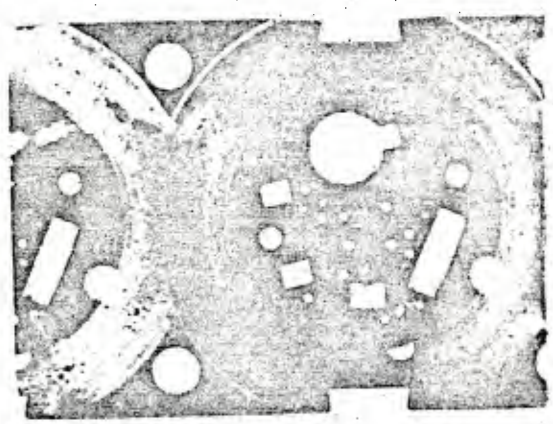


Figure 24 : Bottom plate of a watch

Problems in the use of sensor systems

Extensive basic investigations have been conducted in the field of digital picture processing since the beginning of the seventies. Supported by the rapid development in the semiconductor and computer fields and also by the accompanying cost reduction in these fields, it has been possible to build picture-processing systems coupled to computers at reasonable costs. But the task-specific software development is still very cost-intensive to the present day. This is one of the reasons why such systems come into use only hesitantly.

Further reasons which hinder the application of such sensor systems are:

- shading effects
- special illumination equipment
- too low clock time for each test
- sensitivity of sensors, and
- insufficient contrast conditions.

The shading problems at least call for a hardware correction of the picture scene. But it is often experienced that such a correction module is not satisfactory. Measurement must then be integral and the correction is made through software. This in turn partly leads to considerably longer test clock times. Another not insignificant aspect is the demand made on the illumination equipment. While simple plane light sources are sufficient for working in the throughlight illumination mode, to produce clear contrast conditions, working in the vertical illumination mode partly requires the use of rather elaborate special light sources. These special lighting facilities in part lead to a considerable increase in the system price.

The test stations on the shop floor are partly accomodated in a rather rough environment. TV cameras have a very sensitive tube and must therefore be protected from external influences (vibration, heat, etc.).

Due to the reflection behavior of the workpieces, the finding of the contour preceding the inspection task is made very difficult, in particular in the vertical illumination mode. These problems are at present mainly tackled by software correction, but hardware solutions have also been developed for specific picture enhancement algorithms (dilatation, erosion and translation).

Prospects

In the future, reasonably priced and convenient mapped stores and the use of diode-array cameras with steadily growing resolution will extend and improve the applications of picture-processing systems. As a result of drastic price falls, the applications which are now typical in the field of military engineering and medical engineering will experience considerable extension. Optoelectronic sensor systems will enter the production environment on a large scale. The tasks to be expected in quality assurance will particularly be visual inspection, geometry analysis, process supervision, inspection of assembly operations, and pattern recognition for controlling intelligent handling devices.

Furthermore, the teach-in methods which are still necessary at present, will largely be taken over by computer groups, used in divisions like design, development and work scheduling (e.g. CAD, CAM) for making a product.

SUMMARY

It is obvious that the development in production engineering points towards even more rapid, more reasonably priced, more reliable, highly automated flexible manufacturing systems. As a necessary consequence, the demands made on the supervising and controlling units will also rise, particularly with respect to optical units.

Much attention is given to research and development in optical sensor systems, both in the United States and in the Federal Republic of Germany. However technology transfer into industrial applications is definitely lagging.
This then is the starting point for further work in the subject of "sensorics"; in particular the integration of complex non-contact measuring systems into the fields of quality engineering. With the increased use of such highly automated systems, additional changes will become necessary throughout the field of quality assurance, especially with respect to organization. These problems although only briefly outlined in this paper, form a fundamental part of the activities at the IPA.

The experience gained in the use of a wide variety of optical sensors (linear diodes, diode arrays, photosensitive individual elements, complex linear systems, etc,) has resulted in a state of development at the IPA that makes it possible to link individual sensor types to the modular software.
The outcome is a flexible unit, which can be easily converted to changing parameters (data transfer rate, data reduction, cycle speed, etc.).
Under the ICAM project, the field of quality assurance has so far been somewhat neglected. This should be an area of special significance in the aerospace industry, where production of high quality parts is essential.